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THE INHERITANCE OF RACHILLA LENGTH AND ITS RELATION TO OTHER CHARACTERS IN A CROSS BETWEEN AVENA SATIVA AND AVENA SATIVA ORIENTALIS

A THESIS

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL OF CORNELL UNIVERSITY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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The Inheritance of Rachilla Length and Its Relation to Other Characters in a Cross Between Avena Sativa and Avena Sativa Orientalis

(Technical)

By

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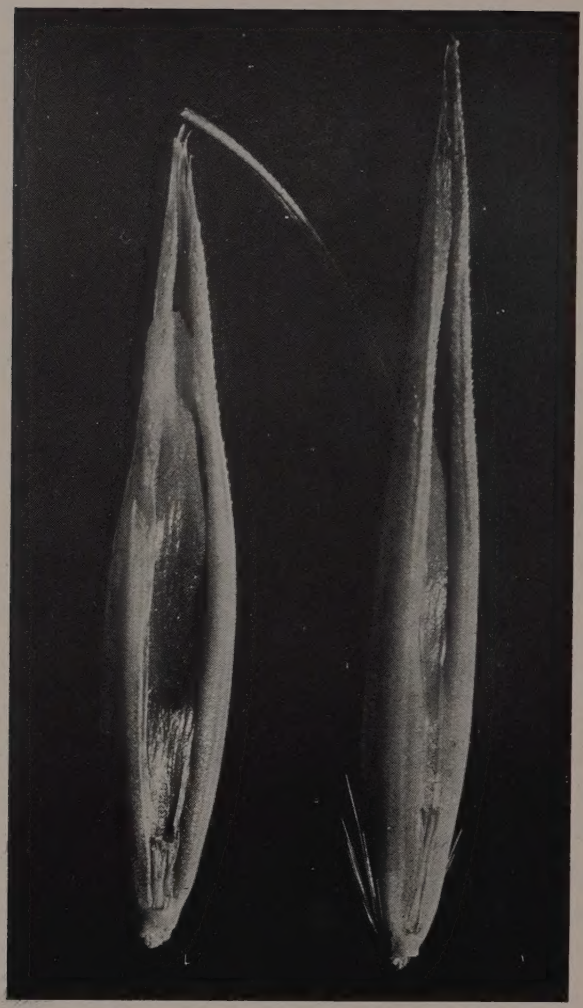

Fig. 1.—Grain types of the parental varieties. Garton 784 on left and Early Gothland on right.

The Inheritance of Rachilla Length and Its Relation to Other Characters in a Cross Between Avena Sativa and Avena Sativa Orientalis

The inheritance of quantitative characters such as yield, size of plant, and others of like nature has been much less extensively studied than the inheritance of qualitative characters. The reason is found largely in the fact that they are usually much less easily analyzed and often present rather complex problems. Quantitative characters are often so influenced by environmental conditions that genetic differences are obscured. A number of workers have, however, demonstrated that the inheritance of size characters may be explained on a factorial basis similar to that of the inheritance of qualitative characters. Sax *(16)*, Lindstrom *(9)* and others have pointed out the desirability of attempting to correlate size characters with easily recognized qualitative characters and thus facilitate the analysis of the former in any inheritance study.

A quantitative character that is relatively stable under varying environmental conditions is obviously very desirable for making a study of the nature of size inheritance. In the present study the size character chosen, length of rachilla in oats, seemed to offer an exceptionally stable character and one that could be studied in relation to a number of definite qualitative characters.

REVIEW OF LITERATURE

East *(2)* made a study of the inheritance of corolla length in a tobacco cross. This study is taken as typical of many size inheritance studies made by East. In this tobacco cross the corolla length in the F_1 generation was intermediate between the two parents and was only slightly more variable than the more variable parent. The F_2 generation ranged between the two parents and had a much greater variability than either the parents or the F_1 generation. In the F_3 and succeeding generations families were recovered with various lengths of corolla. Some of these families showed a variability no greater than that of the parents, while others were more like the F_2 in this respect. The data indicate that the inheritance of this character can

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be explained on a multiple factor basis. In this paper East outlines certain requirements which, if met in a size inheritance study, tend to indicate that the results may be explained on a factorial basis.

Quisenberry *(15)* in a study of the inheritance of length of grain in an oat cross found the F_1 to have grains intermediate in length while the F_2 ranged from one parent to the other. In 150 F_3 families, two were recovered with a mean length as short as the short parent and four with a length as great as the long parent. Between the extremes were lines that apparently bred true for intermediate lengths. The results were explained on the basis that the parents differed by at least three main factors or groups of factors for grain length.

Garber and Quisenberry *(6)* studied the inheritance of date of heading, leaf width, number of culms, and color of seed in another oat cross. Earliness was found to be inherited as a dominant character with evidence of a two factor difference. Leaf width was found to be a variable character. One F_3 family was recovered with a leaf width less than the narrow-leaved parent. The data indicated that this character was controlled by multiple factors. The number of culms was also found to be greatly influenced by environment, but the data indicated that it was an inherited character. Seed color was found to be due to a single factor difference. No evidence of linkage was found between any of the characters studied.

Noll *(14)*, in a study of the inheritance of earliness in crosses between early and late varieties of oats, found the F_1 generation to be as early or earlier than the early parent. The F_2 ranged beyond the extremes of both parents. Homozygous races were obtained in F_3 and F_4 which covered the same range as the F_2. Earliness was apparently due to a series of dominant factors, which together had a cumulative effect. The data, the author states, indicate but do not prove conclusively that the factors had the same effect.

Caporn *(1)* crossed an early with a late variety of oats. Two lines out of 106 F_3 families were found to be as early as the early parent but no lines were recovered that were as late as the late parent. The author explains the results obtained on a three factor basis. Late ripening was found to be closely associated with the amount of tillering.

Nilsson-Ehle *(12)* made a study of various size characters. These studies have been reviewed by Hayes and Garber *(8)*. Transgressive segregation was found in oat crosses involving differences in height, leaf width, kernel size, and number of florets per spikelet. The results were explained on a multiple factor hypothesis. Nilsson-Ehle also

obtained transgressive segregation for date of maturity in certain oat crosses. Homozygous forms were obtained in the F_3 progenies which were earlier than the early parent and also some that were later than the late parent.

The linkage of size factors with certain qualitative characters have been noted by several workers. Tedin and Tedin *(18)* crossed a two-rowed hulled with a six-rowed hull-less barley. The two-rowed barley was about ten centimeters higher than the other variety. The inheritance of type of spike and of the hull condition was explained on single factor differences which were independent of each other. Evidence for linkage between the factor for two-rowedness and a factor for plant height was found. The authors state that evidence was also found that heterozygosity in the factor for two-rowedness had a marked "stimulating" effect upon height of plant.

Sax *(16)* studied the relation between size of seed and pigmentation of seed in beans. A linkage was found between factors, or groups of factors, for seed weight and factors for pigmentation and pattern of the seed coat.

Lindstrom *(9)* in a study of inheritance of size of tomatoes found that a factor for size of fruit was linked with a factor for skin color.

Griffe *(7)* using barley, studied the relation of resistance to *Helminthosporium sativum* and certain morphological characters. He concluded that resistance to this disease was controlled by at least three factors or groups of factors apparently linked with the factors determining the character pairs: six-rowed versus two-rowed; black versus white glumes, and rough versus smooth awn. The linkage was not complete as resistance or susceptibility could be combined with any desired morphological character.

MATERIALS AND METHODS

The object of the study reported in this bulletin was to attempt to determine the mode of inheritance of a definite size character, length of rachilla in oats, and its relation to certain other qualitative characters. The material for this study was obtained by making a cross between Early Gothland *(Avena sativa)* and Garton 784 *(Avena sativa orientalis)*.

The Early Gothland parent has a pubescent rachilla approximately 2.7 millimeters long on its lower grain (Fig. 1), while in the Garton 784 parent the rachilla is extremely short, being only approximately 1.6 millimeters long. It is free from pubescence except for an occasional hair.

Early Gothland is a white grained variety, has an open type of panicle (Fig. 2), and has a leaf with a very prominent ligule. The Garton 784 parent has black colored grains, has a side type of panicle, and has no ligule at the juncture of the leaf blade and the leaf sheath. The parental material used all descended from a single panicle of each variety selected from pure line material grown in the Plant Breeding Nursery at Morgantown, West Virginia, in 1921. The reciprocal crosses were made in 1922.

Figure 2.—Panicle types of the parental varieties. Early Gothland on left and Garton 784 on right.

An F_1 generation was grown in the greenhouse during the winter 1922-23. The plants were late in maturing so that only enough seeds were secured to grow an F_2 population of 290 plants in 1923. A few additional F_1 plants and also parental material were grown with the F_2 generation in the field. Larger F_2 populations were grown in 1924 and 1925. A few F_1 plants and also parental material were grown with these each year. In 1925 F_3 families were grown from a number of the F_2 plants.

All material in this study was grown in rows five feet long and spaced one foot apart. Twenty seeds were planted per row. At the end of each row and set off by a small stake, three seeds of Victory oats were planted in order to eliminate border effect as far as possible. These plants were pulled and discarded before any of the plants under study were harvested. When it was necessary to plant only a part of a row of the material under study on account of lack of seed, the remainder of the row was planted to Victory and the plants discarded in the same manner as the border plants.

The F_3 families from which it was planned to get rachilla measurements were all planted in five-row plots except in a few instances where there was not enough seed. Rachilla measurements were made on 60 such F_3 families. In addition to these, 75 families consisting of only one row each were grown in order to get additional data on the relation of the ligule and panicle type. The five-row F_3 families were all from F_2 plants grown in 1924 while the single row families were from both the 1923 and 1924 F_2 plants. The parental material in 1925 was grown in 18 three-row plots distributed among the F_2 and the F_3 families. Both parents appeared at distances of from 23 to 36 rows apart. The average distance apart of the parental material was 30 rows.

A plot of each variety was also grown on rich and poor soil in 1923 for the purpose of studying the influence of the productivity of the soil on the length of the rachilla.

The rachilla measurements were made by means of a pair of proportional dividers (Fig. 3) using a ratio of 10 to 1 and reading the measurements on a millimeter scale. The units in which the measurements are reported are in terms of .1 millimeters. A mounted reading glass was used to facilitate making the readings obtained with the dividers.

The classification of the panicle type and the ligule note were made in the field before the plants were harvsted. The classifications for color of grain and for rachilla pubescence were made at the time that the rachilla was measured.

DETERMINATION OF SIZE OF SAMPLE

Before proceeding with the measuring of the F_2 material it was necessary to make measurements of the rachillas of the parental material in order to determine how many grains would be necessary for a dependable sample from each plant. Preliminary measurements made in 1922 had shown that the length of rachilla did not vary significantly on grains taken from the base to tip on the same panicle nor on grains from different panicles of the same plant. The leading panicle was therefore chosen to represent each plant measured. The grains selected from this panicle were taken in a systematic order from the tip to the base of the panicle..

The preliminary measurements also indicated that the short rachilla parent was probably the more variable as measured by the coefficient of variability. This parent was therefore chosen for making a determination on the size of sample required to represent a plant. For this study 15 grains were taken in systematic order from tip to base of the leading panicle from 100 Garton 784 plants grown in 1923. Samples consisting of three, five, and eight grains from each panicle were then made up from the original 15-grain samples. Frequency distributions were then made of the means as secured by these different samples. The statistical constants obtained are shown in Table 1.

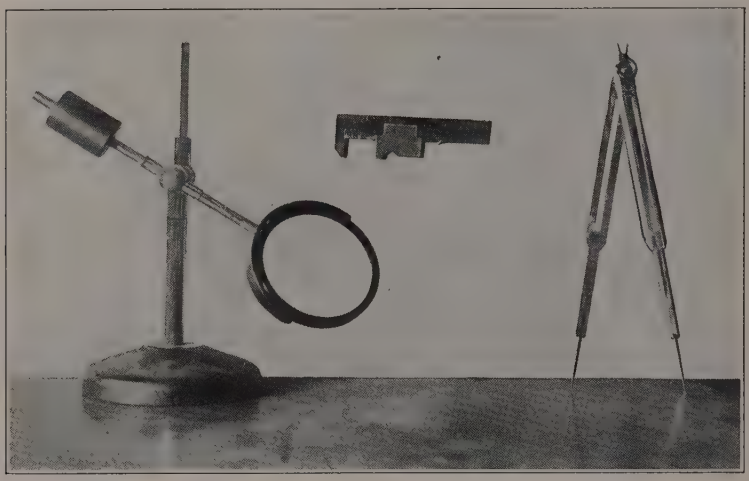

Fig. 3.—Equipment used in making rachilla measurements.

TABLE 1.—Statistical constants for length of rachilla for samples of 3, 5, 8, and 15 grains obtained from 100 plants of the Garton 784 parent grown in 1923.

Number of Grains in Sample	Number of Samples	Means in .1 mm. Units	Standard Deviation	Coefficient of Variability	E_s
3	100	16.570±0.070	1.042±0.050	6.29±0.30	0.703
5	100	16.630±0.065	0.966±0.046	5.81±0.28	0.652
8	100	16.570±0.057	0.852±0.040	5.14±0.24	0.575
15	100	16.510±0.054	0.806±0.038	4.88±0.23	0.544

The data of Table 1 show that there is no significant difference in the means for length of rachilla, whether three, five, eight, or fifteen grains were selected as a representative sample. The standard deviation and the coefficient of variability are reduced as the size of sample is increased. It was decided to use a sample of five grains from each plant as a representative sample for determining the length of rachilla.

DETERMINING THE SIZE OF F_3 FAMILIES

The question also arose as to how many plants it would be necessary to grow in order to obtain a dependable estimate of the breeding behavior for the length of rachilla in any particular family in the F_3 and later generations. This question was of considerable importance in this study on account of the amount of time it required to make the measurements.

For this study the F_2 population grown in 1923 was used. The 290 F_2 plants were first divided into 10 samples of 29 plants each by selecting plants 1, 29, 58, and so on, for sample number one, plants 2, 30, 59, and so on, for sample number two, and proceeding in the same way for the other eight samples. In a similar way six samples of 48 plants each, five samples of 58 plants, and three samples of 96 plants were made up. Statistical constants were then calculated for each of these samples. These constants are given in Table 19 of the appendix. In Table 2 a summary is given of the results obtained.

Since the coefficient of variability is the constant which is frequently used to determine if any F_3 family is homozygous for any given set of size factors, a comparison of this constant in the various samples will give an indication of the number of individuals which

TABLE 2.—Range in means and in coefficients of variability for length of rachilla when samples of 29, 48, 58, and 96 plants were taken from the F_2 generation grown in 1923.

Number of F_2 Plants in Sample	Number of Samples	Range in Means		Range in Coefficients of Variability	
		High	Low	High	Low
29	10	22.172±0.289	21.207±0.295	12.29±1.10	8.00±0.71
48	6	21.917±0.214	20.937±0.215	11.27±0.79	8.91±0.61
58	5	21.690±0.211	21.362±0.174	11.24±0.71	9.19±0.57
96	3	21.875±0.161	21.000±0.142	10.66±0.53	9.48±0.46
290	1	21.652±0.083		9.65±0.27	

will be required to give a trustworthy sample of the F_2 generation. Since no F_3 families with a variability greater than that of the F_2 are ordinarily expected in any cross of this kind involving size factors, any sample that is found satisfactory as a representative of the F_2 population should be large enough to be taken as a trustworthy sample of any of the F_3 and later progenies grown.

Table 2 shows the coefficient of variability ranges from 8.00±0.71 to 12.29±1.10 when samples of only 29 individuals were taken. The wide range in this constant indicates that this would not be a sample large enough to fairly represent the entire F_2 population. When 48 plants were used the coefficient ranges from 8.91±0.61 to 11.27±0.79. The coefficient of variability for the entire population is 9.65±0.27. As the number of individuals in the samples is increased to 58 and 96 respectively the range between the high and low coefficients becomes less. From these data it would seem that about 50 individuals in the F_3 families could be accepted as being a trustworthy sample. On account of the other characters studied in connection with the size character it was decided to plant 100 seeds for each F_3 family where enough seed was available but to measure only a random sample of 50 plants taken from each family.

EFFECT OF SOIL PRODUCTIVITY ON LENGTH OF RACHILLA

In order to study the effect of the productivity of the soil on the length of rachilla a plot of each parent was planted on both rich and poor soil. The rich soil plots were located on land that had at one time been used for gardening purposes and which had received heavy applications of fertilizers and manure. The plots located on the poor

soil were located on a ridge where the soil was in a very low state of productivity. The plots consisted of 15 five-foot rows each.

The heights of all plants were taken before harvest. Each plant was harvested and threshed separately. The grains for measuring were removed from the leading panicle before threshing. One hundred plants taken in order from each plot were used for rachilla length determinations. In tabulating the data obtained, only the yields and heights from the plants on which rachilla measurements were made have been used. A summary of the results obtained is given in Table 3.

TABLE 3.—Means for length of rachilla, yield, and height of individual plants of Early Gothland and Garton 784 parents grown on rich and poor soil in 1923.

Parent	Number of Plants	Kind of Soil	Average Length of Rachilla in .1 mm. Units	Average Yield in Grams	Height in Centimeters
Early Gothland	100	Rich	27.720±0.067	6.95±0.25	114.70±0.55
Early Gothland	100	Poor	25.850±0.076	2.69±0.10	76.05±0.52
Garton 784	100	Rich	16.710±0.055	6.32±0.21	105.15±0.62
Garton 784	100	Poor	16.120±0.053	3.87±0.14	80.35±0.49

It is clearly evident from the results shown in Table 3 that there was a considerable difference in the productivity of the soil between the two plots both as measured by yield and by the height of the plants. The difference between the two plots of Garton 784 was relatively less in both instances than between the plots of Early Gothland.

It is also evident that the productivity of the soil has influenced the length of rachilla in both parents. In the Early Gothland parent the difference between the length of rachilla in the rich and poor soil plots amounts to 1.870±0.101 units and in Garton 784 it is 0.590± 0.076 units. Even with soil differences as extreme as these were, the differences in rachilla length were not large. Evidently this character is very stable and only relatively little influenced by soil differences.

INHERITANCE OF LENGTH OF RACHILLA

The mode or inheritance of length of rachilla was studied by making measurements of the hybrid material as described previously, computing statistical constants, and analyzing the data from a bio-

metrical standpoint. In this cross no significant difference was found between the reciprocal crosses in the inheritance of length of rachilla or in any of the other characters studied. In the tabulations and other data presented the two crosses are, therefore, combined.

A summary of the results obtained in the three years for measurements of the parental material, the F_1 plants, and the F_2 populations is given in Table 4. The data show that the length of rachilla varied only slightly in the different years both in the parents and in the F_2 populations. The means for the Early Gothland parent were 27.512 ± 0.060, 26.608 ± 0.054, and 26.885 ± 0.019 units for the three years 1923, 1924, and 1925, respectively. Between the years 1923 and 1924 there was a difference of 0.904 ± 0.081. This is a relatively small difference but significant in the light of its probable error. The difference between the means of this parent for 1924 and 1925 was 0.277 ± 0.057. The difference is about five times its probable error and indicates that there was less difference in seasonal influences between 1924 and 1925 than between 1923 and 1924. When the means for the years 1923 and 1925 are compared there is found to be a difference of 0.629 ± 0.063. This difference may also be considered as significant.

The coefficients of variability for this parent were 5.52 ± 0.15, 5.69 ± 0.14, and 3.18 ± 0.05 for the three years, respectively. It is obvious that there was no difference in variability in this parent as measured by the coefficient of variability between the years 1923 and 1924. The difference in this constant, however, between the two years 1923 and 1925, 2.34 ± 0.16, shows that this parent was less variable in 1925 than in the other two years. As will be shown later this was also true of the Garton 784 parent.

The means for the Garton 784 parent were 16.731 ± 0.040, 16.119 ± 0.034, and 16.210 ± 0.016 for the three years, respectively. The difference in means for the years 1923 and 1924 was 0.612 ± 0.052 units. This is not a large difference, but is significant in the light of its probable error. The difference in means for this parent between the years 1924 and 1925 was 0.091 ± 0.037, a difference less than three times its probable error and, therefore, not considered significant. The difference in means for the years 1923 and 1925 was 0.521 ± 0.043, which may be considered as a significant difference.

The coefficients of variability for this parent for the three years were 5.89 ± 0.17, 5.38 ± 0.15, and 4.37 ± 0.07, respectively. Between the years 1923 and 1924 there was a difference of 0.51 ± 0.23. This difference is not significant in the light of its probable error and,

TABLE 4.—Statistical constants for length or rachilla of the parents, F_1 and F_2 of the cross Early Gothland by Garton 784 and reciprocal.

Material or Generation	Year	Classes for Length of Rachilla in Units of .1 mm.																			Total No.	Means	Standard Deviation	Coefficient of Variability
		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33				
E. G.	1923											4	15	61	72	74	42	16	8	2	1	295	27.512±0.060	1.518±0.042	5.52±0.15
E. G.	1924										6	19	58	88	82	61	32	3	2	1		352	26.608±0.054	1.513±0.038	5.69±0.14
E. G.	1925												45	223	422	173	18	1				882	26.885±0.019	0.855±0.014	3.18±0.05
G. 784	1923		14	114	88	36	14	2														268	16.731±0.040	0.986±0.029	5.89±0.17
G. 784	1924	1	67	152	63	16	2	1														302	16.119±0.034	0.868±0.024	5.38±0.15
G. 784	1925	1	117	497	253	24	2															894	16.210±0.016	0.708±0.011	4.37±0.07
F_1	1923						1	4	2													7	20.143		
F_1	1924							2	5	1	1											9	21.111		
F_1	1925						1	3	2	1												7	20.429		
F_2	1923			2	3	16	25	49	62	42	35	27	18	6	4	0	0	1				290	21.548±0.087	2.191±0.061	10.17±0.29
F_2	1924			4	12	32	71	86	99	92	54	43	24	8	3	1						529	21.185±0.062	2.116±0.044	9.99±0.21
F_2	1925			2	7	19	57	97	93	87	47	16	8	0	3							436	20.938±0.056	1.734±0.040	8.28±0.19

therefore, this parent is like the Early Gothland in that there was no difference in variability in the first two years of the experiment. Between the years 1924 and 1925 there was a difference of 1.01 ± 0.16, which is significant. The difference for this constant between the years 1923 and 1925 was 1.52 ± 0.18, which may also be considered as an actual difference. Like the Early Gothland parent the Garton 784 parent showed less variability in 1925 than in the other two years.

By means of the coefficient of variability the variability of the two parents may be compared directly. These constants did not differ significantly between the two parents in 1923 and 1924 but in 1925 there was a difference of 1.19 ± 0.09. This shows that in the latter year the Early Gothland parent was less variable than the other parent.

The means for the F_2 populations were 21.548 ± 0.087, 21.185 ± 0.062, and 20.938 ± 0.056 units for the three years 1923, 1924, and 1925, respectively. The difference in means between the years 1923 and 1924 was 0.363 ± 0.107 and between the years 1923 and 1925 it was 0.610 ± 0.103. The difference is approximately three times its probable error in the former case and six times its probable error in the latter case and, therefore, both are considered significant. The difference in means between the years 1924 and 1925 was 0.247 ± 0.084, a difference which is a little less than three times its probable error. The F_2 population, therefore, is like the parents in that the mean length of rachilla in the years 1924 and 1925 was slightly less than in 1923.

An examination of Table 4 shows that in variability, as measured by the coefficient of variability, there was no difference in the F_2 generation for the character under study between the years 1923 and 1924. Between the years 1924 and 1925 there was a difference of 1.71 ± 0.28, which is significant. In respect to variability, therefore, the F_2 showed less range in 1925 than in the previous years and was similar to the parents in this respect.

In all three years the F_1 plants showed a rachilla length which was approximately intermediate between the parents. The F_2 population ranged between the two parents although in no year were plants obtained with rachillas reaching the extremes of the parents.

The variation in length of rachilla from parent to parent in the F_2, with the mean of the population approximately midway between them and also a gradual falling off in numbers in the classes from the mid point to the two extremes, suggests that the inheritance of the length of rachilla can probably be best explained on a multiple factor basis.

If the factors concerned in the inheritance of this character were of equal value and had a cumulative effect, a normal frequency curve would be expected in plotting any F_2 distribution. As may be seen from Table 4, the type of curve obtained in plotting the F_2 distributions obtained in any year shows a considerable variation from a normal frequency curve. Skew curves such as the ones obtained suggest that the factors involved are either of unequal value in determining the length of rachilla or are modified by factors of unequal value.

BREEDING BEHAVIOR OF F_3 PROGENIES FOR LENGTH OF RACHILLA

Sixty-one F_2 plants from the 1924 F_2 generation were grown in F_3 families in order to test their breeding behavior for the inheritance of the length of rachilla. One of these families, 18-2-48 row 290, produced only seven plants. No measurements were made on these plants due to the lack of sufficient numbers. In subsequent tables this family is left out of consideration thus leaving 60 families on which measurements for length of rachilla were obtained. The F_2 plant from which this family was grown was continued in F_3, even if there were only a few seeds available because it seemed to be a False Wild oat plant. This proved to be the case as shown by its behavior in the F_3.

In four other F_3 families, 18-4-77, 18-5-31, 19-1-65, and 19-4-27 the number of plants matured were 45, 43, 38, and 15, respectively. The small number of plants in these families was due to lack of seed. In all other cases 50 plants were used for making length of rachilla determinations. The data obtained in measuring the length of rachilla of the F_3 families and of the parental material grown with these are shown in tables 20, 21, and 22 of the appendix.

In choosing the F_2 plants for continuing in the F_3, a number from each class for length of rachilla were chosen. The number from each class was approximately in proportion to the total number in that class in the entire F_2 population, except that nearly all the plants in the extreme classes were included. The plants were also chosen so that they would afford a test for the breeding behavior of the other characters studied.

A comparison of the distribution of the entire F_2 population and of the F_2 plants selected for continuing in the F_3 is shown in Table 5.

A distribution was obtained which represented the F_2 population fairly well, except for the extreme classes where proportionally more plants were included than in the intermediate classes. If the inheritance of length of rachilla is explained on a multiple factor basis, it

TABLE 5.—Comparison of the total number of F_2 plants, grown in 1924, in various classes for length of rachilla and the number from each class continued in F_3 progenies.

Plant Designations	Classes for Length of Rachilla in Units of .1 mm.						
	15-16	17-18	19-20	21-22	23-24	25-26	27-28
Total No. F_2 plants . .	4	44	157	191	97	32	4
F_2 plants tested in F_3	4	6	12	19	9	7	3

would be expected that there would be a greater probability of the extremes breeding true for a certain length of rachilla than any of the intermediate classes. For this reason more of the extreme classes were included.

CORRELATION BETWEEN F_2 PLANTS AND THEIR F_3 PROGENIES

In order to determine to what degree the length of rachilla is inherited, a correlation coefficient was calculated for the means of the F_2 plants continued in the F_3 and the means of these F_3 families. The distributions are shown in Figure 4.

Length of Rachilla in F_2	Mean Length of Rachilla in F_3										
	17	18	19	20	21	22	23	24	25	26	Total
16	2	2									4
17		1	2								3
18		2	1								3
19		2	1	1	2						6
20				1	4	1					6
21				5	3	1	1				10
22				1	4	4					9
23						2	1	1			4
24						4	1				5
25						1		2			3
26							1	1	1	1	4
27						1		1			2
28										1	1
Total	2	7	4	8	13	14	4	5	1	2	60

$r = 0.886 \pm 0.019$

Fig. 4.—Correlation between average length of rachilla in F_2 plants and the mean length of rachilla in their F_3 progenies.

The coefficient obtained, $r = 0.886 \pm 0.019$, indicates that length of rachilla is an exceptionally stable size character, and that the F_2 gives a good indication of what may be expected in the F_3 progeny from any plant.

VARIABILITY IN F_3 PROGENIES

The coefficient of variability was used as a criterion for determining which F_3 families were breeding true for certain rachilla lengths and which appeared to be heterozygous for the factors determining this character.

The coefficients of variability ranged from 2.55 ± 0.18 to 3.61 ± 0.24 for the various plots of the Early Gothland parent grown in 1925 (Table 20). In the Garton 784 parent this constant varied from 3.26 ± 0.22 to 5.01 ± 0.34 (Table 21). For the F_2 grown this year the coefficient is 8.28 ± 0.19 (Table 4). Omitting family 19-5-13, which segregated for false wild oats and is therefore not considered in this comparison, the F_3 progenies varied from 4.06 ± 0.27 to 9.09 ± 0.61 (Table 22). In Table 6 a frequency distribution has been made of the coefficients of variability and of mean length of rachilla for the different F_3 families.

TABLE 6.—Variability in length of rachilla in the F_3 progenies grouped by classes for length of rachilla.

Mean Length of Rachilla in units of .1 mm.	Classes for Coefficient of Variability of the F_3 Progenies											
	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	Total No.
17	1			1								2
18								2	1	1	3	7
19				1				1	1		1	4
20				1	2		1	1	2	1		8
21			3	1		1	1	3	2	1	1	13
22	1			3	5	1	1		2			13
23				1	2	1						4
24			1	1	1	1		1				5
25		1										1
26		1		1								2
Totals	2	2	4	10	10	4	3	8	8	3	5	59

If the highest coefficient for the parental material (5.01 ± 0.34) is taken as marking the upper limit of variability expected in lines homozygous for a certain length of rachilla, we find there is one family breeding true for a rachilla length of 17, three for 21, one for 22, one for 24, one for 25, and one for 26. Apparently one family has been recovered breeding true for approximately the same length of rachilla as the Garton 784 parent and also one with a rachilla approximately as long as the Early Gothland parent. Between these extremes there are on this basis six other families breeding true for intermediate lengths. If a three factor difference with all factors of equal value be assumed, it would be expected to recover one family breeding true for each extreme and six intermediate homozygous families in a random sample of 64 individuals. The distribution of the homozygous families among the various intermediate classes for length of rachilla is not in very close agreement with what would be expected on such a three factor basis. The F_3 breeding behavior supports the theory that the inheritance of length of rachilla may be put on a multiple factor basis, and also that the factors concerned are either not of equal value or are modified by factors of unequal value.

INHERITANCE OF OTHER CHARACTERS

The inheritance of ligule, panicle type, color, and rachilla pubescence was studied both independently and in their interrelation to each other and to the length of rachilla.

Inheritance of Ligule

The Early Gothland parent in this cross had a leaf with a prominent ligule at the juncture of the leaf blade with the leaf sheath, while the Garton 784 parent was without a ligule. The ligule is ordinarily a very easy character to classify in inheritance. Occasionally, however, a plant is found where the ligule is so poorly developed that it resembles a liguleless plant. In the 60 F_2 plants continued in F_3 one plant should have been classed as liguled that was classed as liguleless and one plant where the opposite was the case (Table 23). The F_1 plants were all liguled indicating that the liguleless character is recessive.

Table 7 presents the results obtained with this character in the F_2 population.

The results obtained are practically identical with the calculated ratio when it is assumed that the inheritance of this character is due to two independently inherited duplicate factors. Love and Craig *(11)* found that inheritance of ligule was due to a one factor difference in

TABLE 7.—Inheritance of ligule in the F_2 generation.

Year	No. of F_2 Plants		Deviation	Probable Error	Dev. / P. E.
	Liguled	Ligulelless			
1923	270	20			
1924	495	34			
1925	411	25			
Observed total	1176	79			
Calculated 15:1 ratio	1176.6	78.4	0.6	5.81	0.10

some varieties of oats and two in others. Garber *(5)* found a two factor difference for the inheritance of this character. Nilsson-Ehle *(13)* found that this character segregated in a monohybrid ratio in one cross while in others its inheritance could be explained on the basis of a two or three factor difference.

In all the different F_2 populations grown it was found that the liguleless condition was very closely associated with the side type of panicle. On account of this relationship between these two characters it is necessary to take both into consideration in analyzing the data for either one in the F_3.

If the liguled condition is dependent upon a two factor difference as the F_2 generation indicates, it would be expected that all liguleless F_2 plants would breed true in the F_3 generation while some of the liguled forms would breed true for this condition and others segregate. In one-half of the segregating lines a 15 to 1 ratio would be expected and in the others a monohybrid ratio.

With the one exception previously mentioned all liguleless F_2 plants continued in the F_3 bred true for this condition. Evidently this plant should have been classed as liguled. The breeding behavior of the F_2 plants in the F_3 progenies for the various characters studied is given in Table 23 of the appendix.

Inheritance of Panicle Type

The Early Gothland parent has an open, spreading panicle while Garton 784 is characterized by a side or "horsemane" type of panicle. The F_1 plants were all intermediate. There seemed to be considerable variation in the expression of this character, some of the F_1 plants resembling the open type more than the side type while in others the reverse was true. The expression of this character appears to be influenced considerably by the environmental conditions and by the stage of maturity of the plants.

The inheritance of panicle type was apparently closely associated with or influenced by the factors producing the liguleless condition. No open liguleless forms were found among any of the F_2 populations grown. This relation suggests that there either is a very close linkage between one of the factors for ligule and the factor or factors for panicle type or that the absence of both of the factors for the liguled condition prevents the factor or factors for open panicle from functioning. Since no open liguleless plants were found among the 1255 F_2 plants grown, it was assumed that the latter was the case. On the assumed basis that the liguled condition is dependent on independently inherited duplicate factors and the open panicle type depends on a single factor difference independent of the two factors for ligule, but inhibited from functioning by the absence of both of the factors for ligule, it would be expected to obtain in F_2 a proportion of 45:15:4 of open panicled liguled plants, side panicled liguled, and side panicled liguleless plants, respectively, or a proportion of 45 open to 19 side panicled plants. The results obtained and the calculated numbers are presented in Table 8.

TABLE 8.—Inheritance of panicle type in the F_2 generation.

Year	No. of F_2 Plants		Deviation	Probable Error	Dev. / P. E.
	Open Panicle	Side Panicle			
1923	191	99			
1924	380	149			
1925	280	156			
Observed total	851	404			
Calculated 45:19 ratio	882.4	372.6	31.4	10.92	2.88

The agreement of the observed with the calculated is fairly good, the difference being 2.88 times its probable error. In one out of 18 chances a deviation as large as this might be expected from random sampling and, therefore, the hypothesis appears plausible. The F_2 population grown in 1924 agrees much better with the theoretical than do those grown in either of the other two years, the deviation being only a little more than its probable error. The F_3 breeding behavior of the F_2 plants grown in 1924 shows that the classification for panicle type was relatively free from errors. One plant was evidently classed as side which should have been classed as open while in another case the reverse was true.

The breeding behavior of the F_2 plants grown in 1923 when tested in F_3 progenies shows that two plants classified as side in that year should have been classed with the open panicled class. These plants segregated for panicle type and, therefore, were heterozygous for this character. The high percentage of side panicle plants in the 1925 F_2 population suggests that in this year, also, probably a number of the plants classed as side panicled were actually heterozygous for this character and should have been classed with the open panicle forms. When the fact is taken into consideration that this character seems to be considerably influenced by environment and thus overlapping of classes is likely to occur, the data undoubtedly support the theory that in this cross the inheritance of panicle type is due to a single factor difference.

When the two characters, ligule and panicle type, are considered together the results shown in Table 9 were obtained.

TABLE 9.—Inheritance of ligule and panicle type in the F_2 generation.

Year	Ligule Present		Ligule Absent	
	Open	Side	Open	Side
1923	191	79	0	20
1924	380	115	0	34
1925	280	131	0	25
Observed total	851	325	0	79
Calculated 45:15:4 ratio	882.4	294.1	0	78.4

$X^2 = 4.368$ $P = 0.116$

Without correcting for the apparent errors in classification in 1923 and 1925, the observed shows only a fair agreement with the calculated, $P = 0.116$ or 12 times in 100 trials would deviations as great as these be expected from chance selection. If the 1924 population alone is considered, the fit is very close; the calculated being 372, 124, and 33, while the observed were 380, 115, and 34 for the three classes, respectively. X^2 is less than one showing a very close fit. The data give further evidence in support of the assumed factorial analysis for the inheritance of ligule and panicle type.

A summary of the breeding behavior for ligule and panicle type of the F_3 progenies grown from the 1924 F_2 plants in the five-row plots is given in Table 10.

TABLE 10.—Breeding behavior for ligule and panicle type of the F_3 progenies grown in 5-row plots in 1925.

F_2 Plants	Number of F_2 Plants	F_3 Progenies								
		Liguled			Seg. for Ligule			Liguleless		
		Open	Seg.	Side	Open	Seg.	Side	Open	Seg.	Side
Open liguled	21	8	6	1		6				
Corrected	20	8	6	0		6				
Side liguled	22			1			20			1
Corrected	23			2			21			0
Side liguleless	17						1			16
Corrected	17						0			17
Total (Corrected)	60	8	6	2		6	21			17
Calculated	60	3.1	6.2	10.7		10.6	12.3			17

The 21 F_2 plants classed as open-liguled bred as follows in the F_3 progenies: Eight bred true to the open-liguled condition, six bred true for ligule but segregated for panicle, one bred true for side-liguled, and six segregated for both ligule and panicle. The F_2 plant producing the side-liguled progeny should evidently have been classified as side-liguled in the F_2 and has, therefore, been added to this class in the corrected tabulation.

The number of families in each class obtained from the open-liguled plants agrees fairly well with the calculated.

With the exception of one plant which segregated for ligule all the F_2 plants classed as liguleless bred true for this condition. In the corrected totals the plant segregating for ligule is classed with the side-liguled plants.

All of the F_2 plants classified as side-liguled and continued in the F_3 bred true for side panicle. One plant bred true for the liguleless condition. It should evidently have been classified as liguleless and has been put with this class in the corrected totals.

Of the 23 side-liguled F_2 plants on the corrected basis two bred true for ligule and 21 segregated. The calculated proportion is 10.7 liguled to 12.3 segregating. In this case the observed does not agree very well with the theoretical. Although the numbers are small, it

would seem that for some undetermined reason more of the heterozygous side-liguled plants were selected than of the homozygous ones for continuance in F_3. Some factor may also be present which causes a modification of the expected ratios in this class.

In addition to the foregoing test of the 1924 F_2 plants, 15 additional progenies were grown in single rows. It is realized that the number of plants grown is too small to obtain any definite ratios. The chief aim was to find out if the side and liguleless condition bred true. The results obtained are given in Table 24 of the appendix. Only side panicled plants were used in this supplementary test. All liguleless plants bred true for this condition. One of the side-liguled plants segregated for panicle type and evidently should have been classed as open in the F_2. Two of the other nine side-liguled plants bred true for this condition while seven segregated. Here again the proportion of side-liguled plants breeding true is too small as compared with the calculated.

In addition to the foregoing tests of the F_2 plants grown in 1924, 65 single row families were grown from the 1923 F_2 plants. The results obtained are shown in Table 25 of the appendix. A summary is presented in Table 11.

TABLE 11.—Breeding behavior of F_3 progenies from 1923 F_2 plants grown in single rows in 1925.

F_2 Plants	Number of F_2 Plants	F_3 Progenies								
		Liguled			Seg. for Ligule			Liguleless		
		Open	Seg.	Side	Open	Seg.	Side	Open	Seg.	Side
Open liguled	11	3	6			2				
Corrected	13	3	7			3				
Side liguled	34		1	3		1	29			
Corrected	33		0	3		0	30			
Side liguleless	15						1			14
Corrected	14						0			14
Total (Corrected)	60	3	7	3		3	30			14
Calculated	60	2.0	4.0	15.4		7.0	17.6			14

Two plants classified as side panicled in 1923 segregated for panicle in the F_3 test in 1925. They evidently were heterozygous and should have been classed with the open panicle group. Likewise one of the plants classed as liguleless was heterozygous. Again in this test there were too many of the side-liguled F_2 plants segregating for ligule in the F_3 progenies as compared with the class breeding true for ligule and side panicle.

In the three tests made of the breeding behavior of ligule and panicle type in the F_3 progenies, the results obtained agree fairly satisfactorily with the calculated except in the case of the proportion of progenies breeding true for the side-liguled condition and those segregating for ligule and breeding true for side panicle. The results indicate therefore that panicle type is conditioned by a single factor difference. It also seems safe to conclude that the presence of both factors for the liguleless condition in the homozygous state prevents the development of an open panicle.

Nilsson-Ehle *(13)* explained the inheritance of panicle type on the basis of one, two, and three factor differences in various oat crosses. A very close association was found between panicle type and ligule in certain crosses. No open liguleless forms were obtained in any of the crosses made. In one cross between an open-liguled variety and a liguleless side-panicle variety, the results obtained were explained on the basis that two independent duplicate factors for ligule were present in the liguled parent and that both of these factors had an influence on the panicle type. The presence of one of these factors alone would produce an intermediate panicle. The other factor alone would produce an intermediate panicle also, but more dense than the former while the absence of both would result in a side panicle. In other crosses there were apparently factors for panicle type present which did not influence the ligule and also factors which would produce a ligule but did not affect the panicle type.

Quisenberry *(15)* found a two factor difference for panicle type in the oat cross which he studied. Gaines *(3)* and also Wakabayshi *(19)* found irregular segregation for panicle type in the F_2 generation and obtained forms breeding true for the intermediate condition as well as for open and side panicles in the F_3 progenies. Garber *(4)* obtained results indicating a one factor difference for the inheritance of panicle type.

Inheritance of Color

In this cross the Early Gothland has a white grain while the color of the Garton 784 grain is black. The plants in the cross were either classed as black or white, no attempt being made to make further divisions on the basis of intensity of the color. The F_1 plants all had black seed indicating that black is dominant. The segregation in the different F_2 populations is shown in Table 12.

TABLE 12.—Inheritance of color of grain in the F_2 generation.

Year	Number of F_2 Plants		Deviation	Probable Error	Dev. / P. E.
	Black	White			
1923	223	67			
1924	403	126			
1925	309	127			
Observed total	935	320			
Calculated 3:1 ratio	941.25	313.75	6.25	10.32	0.61

The observed numbers agree very closely with a 3:1 ratio and indicate that color in this cross is due to a single factor difference.

In classifying the F_3 lines for color of grain the first fifteen plants were used as a basis for the determination, except in ten of the segregating lines where a count was made for a verification of the F_2 ratios. A summary of the breeding behavior for color of the F_3 lines is given in Table 13.

TABLE 13.—Summary of breeding behavior for color of the F_3 progenies.

Color of F_2 Plant	F_3 Breeding Behavior			
	Black	Segregating	White	Total Families
Black	13	27		40
White			20	20
Observed	13	27	20	60
Calculated	13.3	26.7	20	60

All F_2 plants classed as white bred true for this color while those classified as black segregated in the ratio of 13 to 27 for lines breeding true for black and lines segregating for color. The calculated is 13.3 to 26.7. The F_3 breeding behavior, therefore, verifies the assumption

that a one factor difference is concerned in the inheritance of this character. These results are in agreement with results obtained by Love and Craig *(10)*, Gaines *(3)*, Garber and Quisenberry *(6)*, and other workers. Nilsson-Ehle *(13)* found three separately inherited color factors each allelomorphic to its absence in a certain oat cross. Through the interaction of these factors four classes for color were obtained, black, gray, yellow, and white. Other workers have also reported similar results when certain crosses were made.

Inheritance of Rachilla Pubescence

The study of the inheritance of pubescence on the rachilla was based on the rachilla of the lower grain. The Early Gothland parent has a rachilla usually with a number of rather fine hairs. The Garton 784 parent has a smooth rachilla with only an occasional hair on some grains. In classifying plants for this character the five seeds from each plant used for making rachilla measurements were also used for making the pubescence determination. A plant was classed as hairy if any hairs were found on any of the grains examined. Since an occasional hair is sometimes found in the smooth parent this classification results in some overlapping of classes. The F_1 plants all had smooth rachillas. The results obtained in the F_2 populations are given in Table 14.

TABLE 14.—Inheritance of rachilla pubescence in the F_2 generation.

Year	Number of F_2 Plants		Deviation	Probable Error	Dev. / P. E.
	Smooth	Hairy			
1923	225	65			
1924	355	174			
1925	331	105			
Observed total	911	344			
Calculated 3:1 ratio	941.25	313.75	30.25	10.32	2.94

The total observed numbers agree fairly well with the calculated, the deviation being slightly less than three times its probable error. The proportions in the years 1923 and 1925 agree very closely with the calculated 3:1 ratio while in 1924 there were too many in the hairy class. It would seem that for some reason there was more overlapping of classes for this character in this year than in the other two. A check on this is afforded by the breeding behavior of the 60 F_3 progenies grown from 1924 F_2 plants and which were classified for this character.

In classifying the F_3 families for rachilla pubescence the first fifteen individuals were used as a basis for classifying the families. In a number of the segregating families counts were made of the proportion of smooth and hairy individuals in order to check the ratios obtained in the F_2 generation.

A summary of the breeding behavior for rachilla pubescence in the F_3 progenies is shown in Table 15.

TABLE 15.—Summary of breeding behavior for rachilla pubescence in the F_3 progenies.

Classification of F_2 Plant	F_3 Breeding Behavior			Total Number of Lines
	Smooth	Segregating	Hairy	
Smooth	14	27	1	42
Hairy		4	14	18
Observed (Corrected)	14	31	15	60
Calculated	15	30	15	60

From the 42 F_2 plants classified as smooth, 14 lines bred true for this condition, 27 segregated for smooth and hairy, and one bred true for the hairy condition. Evidently this latter plant should have been classified as hairy in the F_2. Fourteen of the F_2 plants, classified as hairy, bred true, while four segregated. On the assumed basis of a one factor difference with smooth condition dominant, these four plants should have been classified as smooth in the F_2. When these F_2 plants are reclassified on the basis of their breeding behavior the number of lines breeding true and the number segregating agree very closely with the calculated. The observed are 14 to 31, and the calculated 15 to 30, respectively. The F_3 breeding behavior, therefore, verifies the assumption that rachilla pubescence in this cross is due to a single factor difference with smooth rachilla dominant.

On the basis of the breeding behavior in the F_3 and assuming that the same proportion of overlapping of classes occurred in the remainder of the F_2 classification in 1924, 30 plants should be changed from the hairy class to the smooth class in the 1924 F_2 population. If this were done, the observed and calculated totals for the three years would be:

	Smooth	Hairy
Observed	941	314
Calculated	941.25	313.75

A number of individuals were, no doubt, classed in the wrong group in the other years, also, so that the close fit is probably coincidental.

Surface *(17)* found that pubescence of the rachilla together with six other characters were completely linked with wild base in a cross between wild and cultivated oats. These were all inherited in a monohybrid ratio. Absence of rachilla hairs was found dominant to the hairy condition.

INTERRELATION OF CHARACTERS

In order to determine if any of the characters studied tended to be associated in their inheritance, the F_2 plants were classified in various combinations. The breeding behavior of the F_3 progenies shows that some of the F_2 plants were wrongly classified for rachilla pubescence. Since only the 1924 F_2 can be checked from the breeding behavior of the F_3 progenies, the F_2 grown in this year is used in the various groupings where rachilla pubescence is one of the characters studied. With the exception of the relation found between the ligule character and panicle type, which has already been discussed, no association in inheritance was found between any of the qualitative characters studied. Table 16 is presented as typical of the method used. All the different qualitative characters studied are included in this table.

In Table 16 the correction for pubescence has been applied as in the other tests with this character. The deviation from the calculated is such as might be expected by chance two times in five trials, $P = 0.410$. From these tests it seems safe to conclude that the four characters are all conditioned by factors that are independently inherited and that the relation between the factor differences which cause panicle type and the liguled condition is of the nature assumed.

CORRELATION OF RACHILLA LENGTH WITH OTHER CHARACTERS

In order to determine if there is any correlation between the inheritance of length of rachilla and any of the other characters studied, the means were calculated for the F_2 plants in each contrasting class for the various characters. If there was no significant difference found in the means between any two contrasted classes it was concluded that no correlation existed between that particular character and the length of rachilla. In addition to this test the means for length of rachilla of the F_3 progenies breeding true for the contrasted characters and those segregating were thrown into frequency distributions from which a mean of means was calculated for each class. The relationship between any character and the length of rachilla could thus be studied in these progenies and the results could then be used as a check on the results obtained in the F_2 generation.

TABLE 16.—Inheritance of ligule, panicle type, color, and rachilla pubescence in the F_2 generation grown in 1924.

Observed and Calculated	Number of F_2 Plants															
	Liguled								Liguleless							
	Open Panicle				Side Panicle				Open Panicle				Side Panicle			
	Black		White		Black		White		Black		White		Black		White	
	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy
Observed	192	102	68	18	49	35	20	11	0	0	0	0	19	6	7	2
Observed (Corrected)	209.8	84.2	71.1	14.9	55.1	28.9	21.9	9.1	0	0	0	0	20.0	5.0	7.3	1.7
Calculated	209.2	69.7	69.7	23.2	69.7	23.2	23.2	7.7	0	0	0	0	18.6	6.2	6.2	2.1

$X^2 = 11.411 \qquad P = 0.410$

Pubescence and Length of Rachilla

In Table 17 the means for the pubescent and the smooth segregates in the F_2 populations and the means for the F_3 progenies breeding true for the hairy condition, segregating, and breeding true for smooth rachilla are compared.

The data show that in all three F_2 populations the means for the length of rachilla were greater for the hairy segregates than for the smooth and in no case was the difference less than ten times its probable error. This is taken as evidence that the characters pubescence of rachilla and length of rachilla are definitely associated in inheritance.

As a further test of this relationship, coefficients of contingency were calculated for pubescence and length of rachilla in the F_2 generations. The following coefficients were obtained in the various F_2 populations: 1923, $C = 0.346 \pm 0.046$; 1924, $C = 0.416 \pm 0.033$; 1924, $C = 0.321 \pm 0.039$. In all three years there was a positive correlation between these two characters. This method of analysis, therefore, also shows the linkage relation which exists between pubescence and length of rachilla in their inheritance.

When the F_3 generation is considered it is also seen that the families breeding true for the hairy condition had a greater mean length of rachilla than either the segregating families or those breeding true for smooth rachilla. The families segregating for this character also had a greater mean length of rachilla than those breeding true for the smooth condition. In no case was the difference less than three times its probable error. This is further confirmation that these two characters are definitely associated in inheritance.

Since it has been shown that the inheritance of pubescence of the rachilla is dependent upon a single factor difference and that the length of rachilla may be explained on a multiple factor basis, it seems logical to conclude that the factor determining the inheritance of pubescence of the rachilla is in the same linkage group as one or more of the factors determining the length of rachilla.

TABLE 17.—Length of rachilla in the pubescent and smooth rachilla segregates in the F_2 generations and the mean length of rachilla in the F_3 progenies breeding true for pubescent rachilla, segregating, and breeding true for smooth rachilla.

Character of Pubescence	Generation	Year	Classes for Length of Rachilla in Units of .1 mm.															Total No.	Means	Difference	Diff. / P. E.
			16	17	18	19	20	21	22	23	24	25	26	27	28	29	30				
Smooth	2	1923	2	3	16	25	48	48	26	25	18	12	2					225	21.089±0.091		
Hairy	2	1923					1	14	16	10	9	6	4	4			1	65	23.138±0.168	2.049±0.191	10.7
Smooth	2	1924	4	11	29	66	73	74	54	25	10	6	3					355	20.485±0.066		
Hairy	2	1924		1	3	5	13	25	38	29	33	18	5	3	1			174	22.615±0.098	2.130±0.118	18.0
Smooth	2	1925	2	6	18	53	85	73	56	29	6	3						331	20.592±0.058		
Hairy	2	1925		1	1	4	12	20	31	18	10	5		3				105	22.029±0.115	1.437±0.129	11.1
Smooth	3	1925		2	3	2	3		3	1								14	19.643±0.345	2.957±0.447*	6.6
Segregating	3	1925			4	2	4	9	8		3		1					31	21.065±0.226	1.422±0.412**	3.4
Hairy	3	1925					1	4	3	3	2	1	1					15	22.600±0.284	1.535±0.363†	4.2

*Between hairy and smooth rachilla progenies.
**Between smooth and segregating progenies.
†Between hairy and segregating progenies.

Ligule, Panicle Type, Color of Grain, and Length of Rachilla

The means for length of rachilla of the various classes for ligule, panicle type, and color were calculated in the same manner as these were calculated for the classes for pubescence of the rachilla. A summary of the results obtained is given in Table 18.

TABLE 18.—Mean length of rachilla in different contrasted classes in the F_2 and F_3 generations.

Description	Generation	Number of Plants and Mean Length of Rachilla in Units of .1 mm.					
		1923		1924		1925	
		No.	Means	No.	Means	No.	Means
Liguled	F_2	270	21.548±0.090	495	21.178±0.065	411	20.934±0.057
Liguleless	F_2	20	21.550±0.311	34	21.294±0.222	25	21.000±0.275
Liguled	F_3					16	20.875±0.331
Seg. for ligule	F_3					27	21.370±0.296
Liguleless	F_3					17	20.882±0.291
Open panicle	F_2	191	21.534±0.110	381	21.097±0.074	280	20.811±0.069
Side panicle	F_2	99	21.576±0.140	148	21.412±0.114	156	21.167±0.094
Open panicle	F_3					8	20.125±0.526
Seg. for panicle	F_3					12	21.250±0.451
Side Panicle	F_3					40	21.250±0.205
Black grain	F_2	223	21.453±0.102	403	20.980±0.070	309	20.861±0.068
White grain	F_2	67	21.866±0.158	126	21.841±0.125	127	21.126±0.097
Black grain	F_3					15	20.800±0.338
Seg. for color	F_3					25	20.400±0.267
White grain	F_3					20	22.150±0.279

It is evident from a consideration of the data given in Table 18 that there was no correlation between the inheritance of the length of rachilla and the inheritance of either ligule or panicle type. The differences between the means for the various classes are not significant in the light of their probable errors.

The differences in length of rachilla between the black and white grained classed in the F_2 generation for the three years were 0.413 ± 0.188, 0.861 ± 0.143, and 0.265 ± 0.118. In two out of the three years the differences were not large enough to be considered significant. In the other year, 1924, the difference was approximately six times its probable error and shows that the white seeded plants had the longer rachillas that year. The fact that there is only a difference in one year out of the three indicates that if this difference was due to inheritance, the association between color and length of rachilla is very loose.

In the F_3 generation there was no significant difference in length of rachilla between the families breeding true for black and those segregating for color. The actual length for the segregating families was less than for the families breeding true for black color. The differences in mean length of rachilla between the segregating and white families was 1.750 ± 0.386 units. This difference is significant in the light of its probable error. The difference between the black seeded families and the white was 1.350 ± 0.438 which may also be considered as significant. These results seem to point to a slight association between the inheritance of color and length of rachilla.

SUMMARY

A cross was made between Early Gothland and Garton 784 two varieties of oats differing in certain characters. A study was made of the inheritance of the length of the rachilla, ligule, panicle type, color, and pubescence of the rachilla. From the results obtained certain conclusions and deductions can be drawn.

1.—The length of rachilla was found to be a very stable size character and was not greatly influenced by environmental conditions.

2.—The length of rachilla in the F_1 plants was intermediate between the two parents. The F_2 individuals ranged from one parent to the other for length of rachilla. From 60 F_3 progenies grown, one apparently homozygous line was recovered with a rachilla length as short as the short parent, and one F_3 family with a rachilla length approximately as long as the longer parent. Families apparently homozygous for rachilla lengths intermediate between these extremes were also recovered. The inheritance of rachilla length can be explained on the basis of multiple factors for length of rachilla. The results indicated that the factors involved were not of equal value in determining the length of rachilla.

3.—The ligule of the leaf was found to be determined by duplicate factors giving a ratio of 15 liguled to 1 liguleless plant in the F_2 generation.

4.—The panicle type was found to be controlled by a single factor difference. The presence of the two factors for the liguleless condition in the homozygous state prevented the factor for open panicle, if present, from functioning and resulted in producing a side panicle. No open panicled liguleless forms were found.

5.—Black color of grain was dominant to white. Inheritance of color was controlled by a single factor difference.

6.—Pubescence of the rachilla was found to be recessive to the smooth condition and was controlled by a single factor difference.

7.—No evidence of linkage was found between the factors for ligule, panicle type, color, or pubescence. All seemed to be inherited independently of each other except for the duplicate relationship between the two factors for ligule and their common relationship to the factor for panicle type.

8.—No evidence was found of linkage between any of the factors for length of rachilla and ligule or panicle type. Some of the data indicated a possible loose linkage between color and length of rachilla.

9.—A close linkage was found between at least one of the factors or group of factors for length of rachilla and the factor for pubescence of the rachilla.

SUPPLEMENT

Since this paper was originally submitted for publication, additional data have been obtained by growing F_4 families from a number of selected F_3 plants. These F_4 families were grown during the summer of 1926 and handled in a way similar to that in which the F_3 and other material was handled in the previous years of the study. In all there were twelve F_4 families grown including progenies from single plants from each of the eight F_3 families which were apparently breeding true for certain rachilla lengths. The data obtained are given in Table 26 of the appendix.

The highest coefficient of variability obtained in the parental material grown in 1926 was 5.84 ± 0.38. If this is taken as the upper limit for the coefficients of variability for homozygous lines it is found that all but two of the F_4 lines are apparently homozygous. Among these are included all F_4 progenies from the F_3 families which were classed as homozygous and also two lines from F_3 families which were classified as heterozygous. If an F_3 family were homozygous for a certain length of rachilla it would be expected that it would continue to show this condition in the F_4 also. Either heterozygous or homozygous F_4 lines might be expected from a heterozygous F_3 family. All data show a very close correlation between the length of the rachilla in the F_3 and F_4 generations.

The F_4 data substantiate the conclusion previously reached that a number of F_3 families had been obtained that were breeding true for certain rachilla lengths.

Data on the other characters studied were also obtained for the F_4 families. These data are not presented here but in all cases they substantiate the conclusions drawn from the study of the previous generations.

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APPENDIX

TABLE 19.—Statistical constants for length of rachilla, for samples of 29, 48, 58, and 96 plants taken from the F_2 generation. grown in 1923.

Sample Number	Classes for Length of Rachilla in Units of .1 mm.															Number of Plants	Means	Standard Deviation	Coefficient of Variability
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30				
1			2	1	3	6	6	4	2	2	1	2				29	22.172±0.289	2.306±0.204	10.40±0.93
2			3	4	4	5	3	2	6	2						29	21.414±0.262	2.190±0.194	10.23±0.92
3	1	0	0	2	8	5	5	3	2	2	1					29	21.448±0.262	2.094±0.185	9.76±0.86
4			4	2	3	8	3	2	4	1	1	0	0	0	1	29	21.621±0.333	2.657±0.235	12.29±1.10
5		1	3	3	2	5	6	7	0	2						29	21.241±0.256	2.045±0.181	9.63±0.85
6	1	2	0	2	5	9	0	5	4	0	0	1				29	21.207±0.295	2.354±0.208	11.10±0.99
7			1	1	9	7	4	5	0	1	1					29	21.310±0.213	1.704±0.151	8.00±0.71
8			1	4	5	4	7	4	1	2	0	1				29	21.552±0.256	2.044±0.181	9.48±0.84
9			1	5	3	8	4	1	2	4	1					29	21.586±0.272	2.174±0.193	10.07±0.90
10			1	1	7	5	4	2	6	2	1					29	21.931±0.253	2.016±0.179	9.19±0.81
1		1	3	4	4	10	10	7	2	6	1					48	21.708±0.206	2.121±0.146	9.77±0.67
2			3	4	9	10	5	4	6	5	0	1	0	0	1	48	21.833±0.240	2.461±0.169	11.27±0.79
3	1	0	2	6	9	13	8	3	3	3						48	21.063±0.183	1.887±0.130	8.91±0.61
4		1	1	4	4	12	7	7	8	2	2					48	21.917±0.195	2.008±0.138	9.16±0.63
5			2	2	11	8	7	10	1	2	3	2				48	21.917±0.214	2.197±0.151	10.02±0.70
6	1	1	5	5	9	10	5	4	7	0	0	1				48	20.937±0.215	2.204±0.152	10.53±0.73

(Continued)

TABLE 19.—Concluded.

Sample Number	Classes for Length of Rachilla in Units of .1 mm.															Number of Plants	Means	Standard Deviation	Coefficient of Variability
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30				
1	1	2	2	3	8	15	6	9	6	2	1	3				58	21.690±0.211	2.380±0.149	10.97±0.69
2			4	5	13	12	7	7	6	3	1					58	21.362±0.174	1.963±0.123	9.19±0.57
3	1	0	1	6	13	9	12	7	3	4	1	1				58	21.500±0.183	2.070±0.130	9.63±0.60
4			5	7	6	16	7	3	6	5	2	0	0	0	1	58	21.603±0.215	2.428±0.152	11.24±0.71
5		1	4	4	9	10	10	9	6	4	1					58	21.586±0.182	2.060±0.129	9.54±0.60
1		2	4	8	8	22	17	14	10	8	3					96	21.813±0.142	2.068±0.101	9.48±0.46
2			5	6	20	18	12	14	7	7	3	3	0	0	1	96	21.875±0.161	2.333±0.114	10.66±0.53
3	2	1	7	11	18	23	13	7	10	3	0	1				96	21.000±0.142	2.056±0.100	9.79±0.48
1	2	3	16	25	49	62	42	35	27	18	6	4	0	0	1	290	21.652±0.083	2.089±0.059	9.65±0.27

TABLE 20.—Statistical constants for length of rachilla of the Early Gothland parent grown in various plots in 1925.

1925 Row Number	Classes for Length of Rachilla in Units of .1 mm.						Total No.	Means	Standard Deviation	Coefficient of Variability
	25	26	27	28	29	30				
604–606		15	27	7	1		50	26.880±0.068	0.711±0.048	2.64±0.18
625–627	2	10	24	13		1	50	27.040±0.085	0.894±0.060	3.31±0.22
648–650	3	16	16	10			45	26.733±0.088	0.879±0.062	3.29±0.23
679–681	6	17	20	7			50	26.560±0.083	0.875±0.059	3.29±0.22
711–713	3	12	24	10	1		50	26.880±0.082	0.863±0.058	3.21±0.22
745–747	4	22	17	7			50	26.540±0.079	0.830±0.056	3.13±0.21
779–781		17	23	7			47	26.787±0.067	0.682±0.047	2.55±0.18
808–810	1	8	25	16			50	27.120±0.070	0.739±0.050	2.72±0.18
839–841	4	15	21	7	1		48	26.708±0.087	0.889±0.061	3.33±0.23
873–875	3	13	23	11			50	26.840±0.079	0.833±0.056	3.10±0.21
905–907	1	12	24	9	4		50	27.060±0.086	0.904±0.061	3.34±0.22
936–938	1	10	25	11	1		48	27.021±0.076	0.777±0.053	2.88±0.20
967–969	2	8	27	12	1		50	27.040±0.076	0.799±0.054	2.95±0.20
1003–1005	4	14	22	6	1		47	26.702±0.086	0.673±0.061	3.27±0.23
1035–1037	4	9	30	4			47	26.723±0.072	0.735±0.051	2.75±0.19
1061–1063	2	7	26	14	1		50	27.100±0.077	0.806±0.054	2.97±0.20
1081–1083	3	7	29	8	3		50	27.020±0.084	0.883±0.060	3.27±0.22
1114–1116	2	11	19	14	4		50	27.140±0.093	0.980±0.066	3.61±0.24

TABLE 21.—Statistical constants for length of rachilla of the Garton 784 parent grown in various plots in 1925.

1925 Row Number	Classes for Length of Rachilla in Units of .1 mm.						Total No.	Means	Standard Deviation	Coefficient of Variability
	14	15	16	17	18	19				
607–609		3	24	20	3		50	16.460±0.067	0.699±0.047	4.25±0.29
628–630		2	26	21	1		50	16.420±0.058	0.603±0.041	3.67±0.25
651–653		3	34	13			50	16.200±0.050	0.529±0.036	3.26±0.22
682–684		3	32	15			50	16.240±0.052	0.550±0.037	3.39±0.23
714–716		4	27	19			50	16.300±0.058	0.608±0.041	3.73±0.25
784–750		15	29	5	0	1	50	15.860±0.071	0.749±0.051	4.72±0.32
782–784		5	27	15	3		50	16.320±0.070	0.733±0.049	4.49±0.30
811–813		9	31	10			50	16.020±0.059	0.616±0.042	3.84±0.26
842–844		7	25	16	2		50	16.260±0.071	0.743±0.050	4.57±0.31
876–878	1	5	24	18	1		49	16.265±0.072	0.750±0.051	4.61±0.31
908–910		3	24	18	5		50	16.500±0.072	0.755±0.051	4.58±0.31
939–941		5	31	12	2		50	16.220±0.064	0.672±0.045	4.14±0.28
970–972		14	26	9	0	1	50	15.960±0.076	0.799±0.054	5.01±0.34
1006–1008		9	23	13	2		47	16.170±0.077	0.780±0.054	4.82±0.34
1038–1040		8	30	8	2		48	16.083±0.068	0.702±0.048	4.36±0.30
1064–1066		11	30	8	1		50	15.980±0.065	0.678±0.046	4.24±0.29
1084–1086		4	33	13			50	16.180±0.053	0.555±0.037	3.43±0.23
1117–1119		7	21	20	2		50	16.340±0.073	0.764±0.052	4.68±0.31

TABLE 22.—Breeding behavior for length of rachilla of the F_3 progenies grown in 1925.

1925 Row Number	N. H. N.	Rachilla Length of F_2 Plant	Classes for Length of Rachilla in Units of .1 mm.															Total No.	Means	Coefficient of Variability
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
654–658	18–1–25	21.2				1	2	5	11	13	8	1	7	1	1				50	21.180±0.181	8.94±0.60
659–663	18–1–29	20.6					1	10	20	9	6	4							50	20.420±0.116	5.96±0.40
664–668	18–1–32	21.6						2	9	14	9	12	3	1					50	21.660±0.132	6.37±0.43
669–673	18–1–66	20.0					3	5	11	13	8	9		1					50	21.000±0.147	7.31±0.49
674–678	18–1–70	17.2		5	6	13	16	5	2	1	2								50	17.600±0.153	9.09±0.61
685–689	18–2–29	19.4			1	2	2	10	11	9	7	7	1						50	20.480±0.169	8.64±0.58
691–695	18–4–22	17.8	1	1	7	7	12	13	5	4									50	18.140±0.153	8.82±0.59
696–700	18–4–42	23.0								2	7	10	14	7	6	4			50	24.020±0.150	6.53±0.44
701–705	18–4–47	22.2							9	15	8	17	1						50	21.720±0.111	5.37±0.36
706–710	18–4–54	19.8				3	2	5	12	10	13	2	2	1					50	20.740±0.165	8.34±0.56
717–721	18–4–56	16.0		1	11	20	15	3											50	17.140±0.086	5.29±0.36
722–726	18–4–58	18.2		1		8	5	12	10	8	5	1							50	19.400±0.164	8.87±0.60
727–731	18–4–68	22.4					2	5	10	16	5	8	2	2					50	21.180±0.156	7.71±0.52
732–736	18–4–76	18.8				1	2	8	11	10	8	8	1	1					50	20.880±0.160	8.05±0.54
737–739	18–4–77	27.8											10	13	13	2	6	1	45	25.867±0.140	5.38±0.38
740–744	18–4–104	19.2		1	1	5	8	17	10	4	3	1							50	19.120±0.149	8.14±0.55
751–753	18–5–31	17.0			1	2	13	16	10	1									43	18.814±0.102	5.28±0.38

(Continued)

TABLE 22.—Continued.

1925 Row Number	N. H. N.	Rachilla Length of F_2 Plant	Classes for Length of Rachilla in Units of .1 mm.															Total No.	Means	Coefficient of Variability
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
754–758	18–5–32	21.0				1	4	11	17	10	3	2	2						50	20.400±0.135	6.93±0.47
759–763	18–5–33	16.4			4	11	12	10	10	2	1								50	18.420±0.136	7.76±0.52
764–768	8–5–34	21.8					1	3	6	10	12	11	2	4	1				50	21.920±0.164	7.84±0.53
769–773	18–5–42	20.0				4	7	15	12	6	3	2	1						50	19.620±0.150	8.02±0.54
774–778	18–5–43	22.2					4	5	22	11	7	1							50	20.300±0.108	5.60±0.38
785–789	18–6–117	19.0		2	4	14	12	12	4	2									50	17.960±0.131	7.63±0.51
790–792	18–6–124	26.8						2	2	9	21	6	7	3					50	22.200±0.131	6.18±0.42
793–797	18–6–131	18.0		3	1	8	16	11	6	2	3								50	18.440±0.154	8.75±0.59
798–802	18–6–135	24.8							1		3	10	16	11	6	2	1		50	24.260±0.137	5.94±0.40
803–807	18–6–136	19.2					2	3	10	12	9	9	4		1				50	21.440±0.157	7.70±0.52
814–818	18–6–155	22.0						3	12	17	10	4	2	1	1				50	21.300±0.138	6.79±0.46
819–823	18–6–169	16.0		3	20	25	2												50	16.520±0.064	4.06±0.27
824–828	19–1–26	17.4				9	14	9	10	6	2								50	18.920±0.136	7.54±0.51
829–833	19–1–34	20.8					2	15	15	9	7	2							50	20.200±0.118	6.10±0.41
834–838	19–1–36	20.8				2	9	15	8	10	4	2							50	19.700±0.141	7.48±0.50
845–849	19–1–41	23.8							2	5	13	13	12	4	1				50	22.880±0.126	5.77±0.39
850–852	19–1–65	16.0		3	6	5	12	8	2	2									38	17.789±0.167	8.57±0.66

(Continued)

TABLE 22.—Continued.

1925 Row Number	N. H. N.	Rachilla Length of F_2 Plant	Classes for Length of Rachilla in Units of .1 mm.															Total No.	Means	Variability Coefficient of
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
853–857	19–3–22	22.6						1	2	5	14	13	13	1	1				50	22.680±0.127	5.88±0.40
858–862	19–3–28	24.4						2	5	14	13	13	3						50	21.780±0.116	5.61±0.38
863–867	19–3–49	25.6									2	17	14	7	8	2			50	24.160±0.121	5.26±0.35
868–872	19–3–55	21.2						4	6	12	5	12	7	4					50	22.040±0.164	7.80±0.53
879–883	19–3–61	19.0			3	8	19	8	8	3	1								50	18.460±0.130	7.37±0.50
884	19–4–27	25.8								4	3	3	3	1	1				15	22.800±0.264	6.64±0.82
885–889	19–4–40	23.2							3	15	15	10	4	3					50	22.120±0.120	5.69±0.38
890–894	19–4–52	22.4						1	9	18	9	8	5						50	21.580±0.122	5.94±0.40
895–899	19–4–88	24.8										15	19	11	1	3		1	50	24.240±0.120	5.19±0.35
900–904	19–4–89	21.4							2	8	14	11	13	1	1				50	22.640±0.123	5.71±0.38
911–915	19–4–94	23.8							2	13	19	14	2						50	22.020±0.088	4.21±0.28
916–920	19–5–13	19.8				1	1	4	11	14	4	3			1	7	3	1	50	22.200±0.297	14.01±0.96
921–925	19–5–15	25.6										4	15	15	11	5			50	24.960±0.106	4.46±0.30
926–930	19–5–16	21.4						5	18	14	11	2							50	20.740±0.099	4.99±0.34
931–935	19–5–17	20.4					1	13	8	9	12	4	2		1				50	20.880±0.159	7.99±0.54
942–946	19–5–32	25.4						1	3	10	15	9	9	3					50	22.340±0.133	6.24±0.42
947–951	19–5–33	23.8						1	5	14	13	6	7	4					50	22.100±0.143	6.79±0.46

(Continued)

TABLE 22.—Concluded.

1925 Row Number	N. H. N.	Rachilla Length of F_2 Plant	Classes for Length of Rachilla in Units of .1 mm.																Total No.	Means	Coefficient of Variability
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
952–956	19–5–35	26.8								1	3	14	10	9	7	2	2	2	50	24.480±0.171	7.32±0.49
957–961	19–5–36	23.4							4	12	8	13	11	2					50	22.420±0.131	6.12±0.41
962–966	19–5–38	20.4					1	10	6	14	12	6	1						50	20.960±0.135	6.75±0.45
973–977	19–6–21	22.4						3	17	20	6	3	1						50	20.840±0.100	5.02±0.34
978–982	19–6–27	20.8				2	3	10	13	12	5	3	1	1					50	20.360±0.156	8.03±0.54
983–987	19–6–32	20.6					1	4	12	16	13	4							50	20.960±0.110	5.48±0.37
988–992	19–6–33	21.6						2	7	14	20	7							50	21.460±0.098	4.77±0.32
993–997	19–6–40	25.6										1	7	18	13	9	2		50	25.560±0.106	4.37±0.29
998–1002	19–6–51	23.6						1	3	12	13	12	7	2					50	22.220±0.127	5.99±0.40

TABLE 23.—Breeding behavior of F_3 progenies for ligule, panicle type, grain color, and rachilla pubescence.

1925 Row Number	N. H. N	Ligule			Panicle Type			Grain Color				Rachilla Pubescence				Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		F_2 Plant	F_3 Families			F_2 Plant	F_3 Families			
			P	A		O	S		B	Seg.	W		Sm.	Seg.	H	
654–658	18–1–25	P	85		O	85		B		x		Sm.		x		85
659–663	18–1–29	P	83	7	O	63	27	B		x		Sm.	x			90
664–668	18–1–32	P	64	18	S		82	B		x		Sm.		x		82
669–673	18–1–66	A		86	S		86	B		x		Sm.		x		86
674–678	18–1–70	P	58	16	O	41	33	B		x		Sm.		x		74
685–689	18–2–29	P	66		O	69	17	W			x	Sm.		x		86
691–695	18–4–22	P	59	25	S		84	W			x	Sm.	x			84
696–700	18–4–42	P		85	O	66	19	B	x			H			x	85
701–705	18–4–47	P	63	26	S		89	W			x	Sm.		x		89
706–710	18–4–54	A		79	S		79	B	x			Sm.		x		79
717–721	18–4–56	P	73	7	O	49	31	B	x			Sm.	x			80
722–726	18–4–58	P	65	21	S		86	B	x			Sm.		x		86
727–731	18–4–68	A		82	S		82	W			x	Sm.		x		82
732–736	18–4–76	P	63	19	S		82	W			x	Sm.		x		82
737–739	18–4–77	P	35	11	S		46	W			x	H			x	46
740–744	18–4–104	P	60	19	S		79	B		x		Sm.	x			79
751–753	18–5–31	P	34	11	S		45	B		x		H		x		45
754–758	18–5–32	A		90	S		90	W			x	Sm.		x		90
759–763	18–5–33	P	79		O	79		B		x		Sm.		x		79
764–768	18–5–34	P	71	18	S		89	W			x	Sm.		x		89
769–733	18–5–42	P	71		S		71	B		x		Sm.		x		71

(Continued)

A = Ligule absent O = Open Panicle B = Black H = Hairy
P = Ligule Present S = Side Panicle W = White Sm. = Smooth
Seg. = Segregating

TABLE 23.—Continued.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Grain Color				Rachilla Pubescence				Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		F_2 Plant	F_3 Families			F_2 Plant	F_3 Families			
			P	A		O	S		B	Seg.	W		Sm.	Seg.	H	
774–778	18–5–43	A		80	S		80	B		x		Sm.	x			80
785–789	18–6–117	A		91	S		91	B		x		Sm.	x			91
790–792	18–6–124	P		50	O	28	22	W			x	H			x	50
793–797	18–6–131	A		77	S		77	B		x		Sm.	x			77
798–802	18–6–135	A		83	S		83	W			x	Sm.		x		83
803–807	18–6–136	A		88	S		88	B	x			Sm.		x		88
814–818	18–6–155	P	73	18	S		91	B	x			H			x	91
819–823	18–6–169	P	80		O	80		B	x			Sm.	x			80
824–828	19–1–26	P	70	15	S		85	B		x		Sm.	x			85
829–833	19–1–34	P	60	18	S		78	B		x		Sm.		x		78
834–838	19–1–36	P	84		O	84		B		x		H			x	84
845–849	19–1–41	A		89	S	89		W			x	Sm.	x			89
850–852	19–1–65	P	41		O	41		B		x		Sm.		x		41
853–857	19–3–22	P	59	25	S		84	B		x		H			x	84
858–862	19–3–28	P	89		O	89		W			x	Sm.	x			89
863–867	19–3–49	P	62	23	S		85	B	x			Sm.		x		85
868–872	19–3–55	A		87	S		87	B	x			Sm.		x		87
879–883	19–3–61	A		76	S		76	B		x		Sm.	x			76
884	19–4–27	P	15		O		15	B		x		H			x	15
885–889	19–4–40	P	80	3	O	32	51	W			x	Sm.	x			83
890–894	19–4–52	A		81	S		81	W			x	H		x		81
895–899	19–4–88	A		73	S		73	B		x		Sm.		x		73
900–904	19–4–89	P	66	22	S		88	W			x	H			x	88

(Continued)

A = Ligule absent O = Open Panicle B = Black H = Hairy
P = Ligule Present S = Side Panicle W = White Sm. = Smooth
Seg. = Segregating

TABLE 23.—Concluded.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Grain Color				Rachilla Pubescence				Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		F_2 Plant	F_3 Families			F_2 Plant	F_3 Families			
			P	A		O	S		B	Seg.	W		Sm.	Seg.	H	
911–915	19–4–94	P	79		O	58	21	B		x		H			x	79
916–920	19–5–13	A	61	24	S		85	W			x	Sm.		x		85
921–925	19–5–15	P	63	22	S		85	B		x		Sm.			x	85
926–930	19–5–16	P	78		O	59	19	W			x	H			x	78
931–935	19–5–17	P	87		O	70	17	B	x			H			x	87
943–946	19–5–32	P	58	21	S		79	B		x		Sm.		x		79
947–951	19–5–33	P	66	17	S		83	B		x		H			x	83
952–956	19–5–35	P	90		O	90		W			x	H			x	90
957–961	19–5–36	P	64	21	S		85	W			x	Sm.	x			85
962–966	19–5–38	A		75	S		75	B	x			Sm.		x		75
973–977	19–6–21	A		86	S		86	B	x			H			x	86
978–982	19–6–27	P		87	S		87	B	x			Sm.	x			87
983–987	19–6–32	P	54	22	S		76	B		x		H		x		76
988–992	19–6–33	P	79		O	79		B		x		H		x		79
993–997	19–6–40	P	75	8	O	50	33	W			x	Sm.		x		83
998–1002	19–6–51	P	69	5	O	45	29	B		x		Sm.		x		74

A = Ligule absent O = Open Panicle B = Black H = Hairy
P = Ligule Present S = Side Panicle W = White Sm. = Smooth
Seg. = Segregating

TABLE 24.—Breeding behavior for ligule and panicle type of single row F_3 progenies grown from 1924 F_2 plants.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Total No.
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		
			P	A		O	S	
1087	18–1–22	P	18		S		18	18
1088	18–1–33	P	14	3	S	9	8	17
1089	18–1–41	P	15	5	S		20	20
1090	18–4–18	P	15	5	S		20	20
1091	18–4–21	P	11	3	S		14	14
1092	18–4–65	P	14	5	S		19	19
1093	18–6–163	A		14	S		14	14
1094	19–3–17	A		16	S		16	16
1095	19–4–47	A		17	S		17	17
1096	19–4–92	A		19	S		19	19
1097	19–5–25	A		17	S		17	17
1098	19–6–22	P	9	7	S		16	16
1099	19–6–41	P	13	3	S		16	16
1100	19–6–43	P	17		S		17	17
1101	19–6–53	P	17	1	S		18	18

TABLE 25.—Breeding behavior for ligule and panicle type of single row F_2 progenies grown from 1923 F_2 plants.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No F_3 Plants		
			P	A		O	S	
1009	18–1–1	P	16		O	16		16
1010	18–1–3	P	12	3	S		15	15
1011	18–1–8	P	9	4	S		13	13
1012	18–1–17	A	7	4	S		11	11
1013	18–1–19	P	8	5	S		13	13
1014	18–2–8	P	13		O	13		13
1015	18–2–11	P	5	5	S		10	10
1016	18–2–12	A		6	S		6	6
1017	18–3–1	P	13	3	S		16	16
1018	18–3–4	P	13	1	O	10	4	14
1019	18–3–10	P	10	5	S		15	15
1020	18–3–18	A		13	S		13	13
1021	18–3–21	P	7	2	S		9	9
1022	18–3–25	P	8	1	S		9	9
1023	18–4–9	A		13	S		13	13
1024	18–5–2	A		11	S		11	11
1025	18–5–3	P	13		S		13	13
1026	18–5–8	P	18		O	18		18
1027	18–5–24	P	12	1	S		13	13
1028	18–6–8	A		14	S		14	14
1029	18–6–11	P	5	2	S		7	7
1030	18–6–13	P	9	5	S		14	14
1031	18–6–16	P	12	3	S		15	15
1032	18–6–4	P	5	7	S		12	12
1033	18–6–23	A		16	S		16	16

(Continued)

TABLE 25.—Continued.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		
			P	A		O	S	
1034	18–6–29	P	9	4	S		13	13
1041	18–6–33	P	8	6	S		14	14
1042	18–6–38	P	11	3	S		14	14
1043	18–6–42	P	9	4	S		13	13
1044	18–6–48	P	15		S	8	7	15
1045	18–6–51	P	9	5	S		14	14
1046	18–6–58	P	11		O	7	4	11
1047	18–6–60	P	12		O	5	7	12
1048	18–6–78	A		13	S		13	13
1049	18–6–85	P	11		O	5	6	11
1050	18–6–86	P	13		S		13	13
1051	18–6–89	P	15	1	O	9	7	16
1052	18–6–92	A		13	S		13	13
1053	18–6–94	P	12	3	S		15	15
1054	18–6–102	P	12	4	S		16	16
1055	18–6–103	A		13	S		13	13
1056	18–6–106	P	13		O	7	6	13
1057	18–6–108	P	13		S		13	13
1058	18–6–109	P	10	7	S		17	17
1059	18–6–111	P	12		O	5	7	12
1060	18–6–113	P	16		O	11	5	16
1067	19–1–1	P	14	6	S		20	20
1068	19–1–2	A		16	S		16	16
1069	19–1–20	A		14	S		14	14
1070	19–2–5	A		16	S		16	16
1071	19–3–4	A		17	S		17	17

(Continued)

TABLE 25.— Concluded.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		
			P	A		O	S	
1072	19–3–5	P	8	3	S		11	11
1073	19–4–1	P	13	5	S		18	18
1074	19–4–5	P	9	4	S		13	13
1075	19–5–2	A		10	S		10	10
1076	19–5–4	P	15	2	S		17	17
1077	19–6–2	P	13	6	S		19	19
1078	19–6–12	P	15	2	S		17	17
1079	19–6–13	P	13	2	S		15	15
1080	19–6–14	P	11	4	S	7	8	15

TABLE 26.—Statistical constants for length of rachilla of the parents and of the F_4 progenies grown in 1926.

1926 Row Number	Material	F_3 Rachilla		Classes for Length of Rachilla in Units of .1 mm.																	Means	Coefficient of Variabiilty
		Length (class)	C. V. (class)	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
501–503	E. G.													5	18	11	10	5	1		50	25.900±0.118	4.78±0.32
504–506	G. 784				16	28	2	1													47	15.745±0.062	4.03±0.28
507–509	18–1–70–32	18	9.0		4	12	14	5	3												38	16.763±0.116	6.34±0.49
510–512	18–4–56–29	17	5.5		4	11	16	8	1												40	16.775±0.102	5.73±0.43
513–515	18–4–77–1	26	5.5										3	9	8	5	10	10	3	2	50	26.240±0.180	7.17±0.48
516–518	18–6–169–1	17	4.0			3	25	14	3												45	17.378±0.071	4.07±0.29
519–521	E. G.												3	6	10	21	10	1			51	25.627±0.109	4.50±0.30
522–524	G. 784			7	21	20	1														49	15.306±0.071	4.80±0.33
525–527	19–4–88–1	24	5.0								14	24	5	2	3						48	22.083±0.103	4.79±0.33
528–530	19–4–94–1	22	4.0							4	23	14	4	2							47	21.511±0.090	4.27±0.30
531–533	19–5–15–23	25	4.5							2	14	16	10	4							46	22.000±0.102	4.65±0.33
534–536	19–5–16–20	21	5.0						1	11	27	7	2								48	20.958±0.077	3.76±0.26
537–539	E. G.												3	12	15	10	10	2			52	25.346±0.120	5.07±0.34
540–542	G. 784			7	31	10	3	2													53	15.283±0.083	5.84±0.38
543–545	19–6–21–1	21	5.0					1	3	19	14	10	1								48	20.625±0.092	4.60±0.32
546–548	19–6–32–1	21	5.5			1	6	25	13	4		1									50	18.280±0.081	4.64±0.31
549–551	19–6–33–1	21	5.0					1	7	20	20	2									50	20.300±0.079	4.09±0.28
552–554	19–6–40–1	26	4.5									6	18	11	6	2	2	1			46	23.783±0.137	5.81±0.41
555–557	E. .G													5	16	9	5	1			36	25.472±0.111	3.87±0.31
558–560	G. 784			6	29	10	1														46	15.130±0.064	4.28±0.30